



A Metric to Quantify Shared Visual Attention in Two-Person Teams

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- Research Associate at the Institute of Ergonomics at TUM since June 2014
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Human Reliability and *Human Factors in Aviation*
- Representative of the Graduate Centre Mechanical Engineering in the Graduate Council
- Ideas / methods presented today were inspired / developed on a three-month research stay at NASA Ames





What I'm doing

Estimate/predict/analyze human error in aviation

Measures: Procedure Handling, Flight parameters,
Communication, Teamwork, Situation Awareness,...

Teams

- “a distinguishable set of **two or more people** who interact **dynamically, interdependently**, and **adaptively** toward a common and valued goal/object/mission, who have each been assigned **specific roles** or functions to perform, and who have a **limited life span** of membership” (Salas, Dickinson, Converse, & Tannenbaum, 1992)
- Why do we need teams?
 - Tasks often **too complex to be accomplishable by individuals**; only by a team (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Cooke, Salas, Cannon-Bowers, & Stout, 2000)
 - Teams can **share total workload** and team members can **monitor each other** (Salas, et al., 1992)
 - Teams often achieve **better performance** than individuals (Lorge, Tuckman, Aikman, Spiegel, & Moss, 1955)

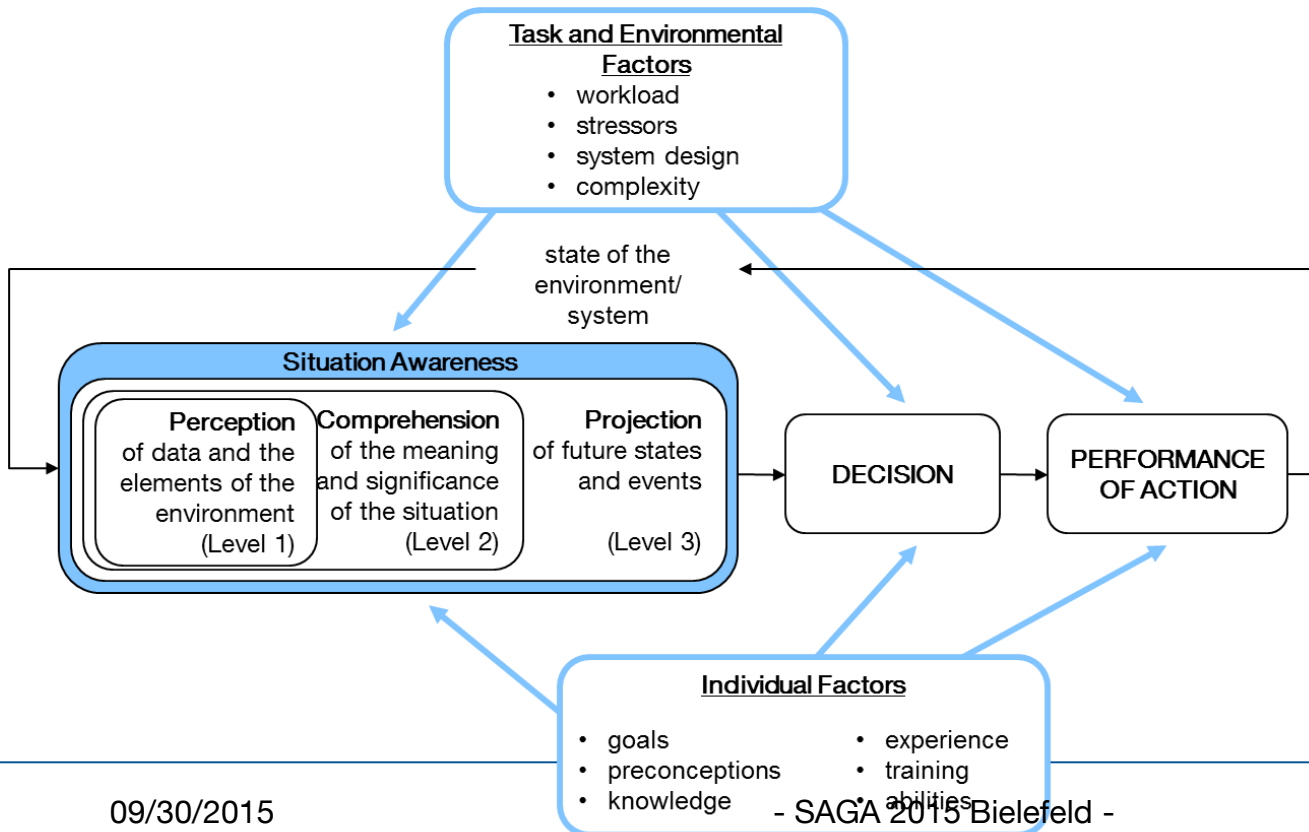
Crew Resource Management

- Training process of teams to **reduce human error** (Helmreich, Merritt, & Wilhelm, 2009)
- Origins in the early 1990s (NASA workshop) in the **aviation domain**
- Meanwhile widely spread in **different domains**

- **Training content** (European Aviation Safety Agency, 2012)
 - Communication
 - Teamwork & Work Organisation
 - **Situation Awareness & Decision Making**
- Current evaluation methods (IRR)

Situation Awareness

“Situational awareness (SA) is the **perception of environmental elements** with **respect to time or space**, the **comprehension of their meaning**, and the **projection of their status** after some variable has changed, such as time, or some other variable, such as a predetermined event.”



- Importance recognized by Endsley (1988)
- Linked with performance
- Majority of in/accidents as a consequence of lack in SA
- Different models to describe SA

According to Endsley (1993)

Situation Awareness of Teams

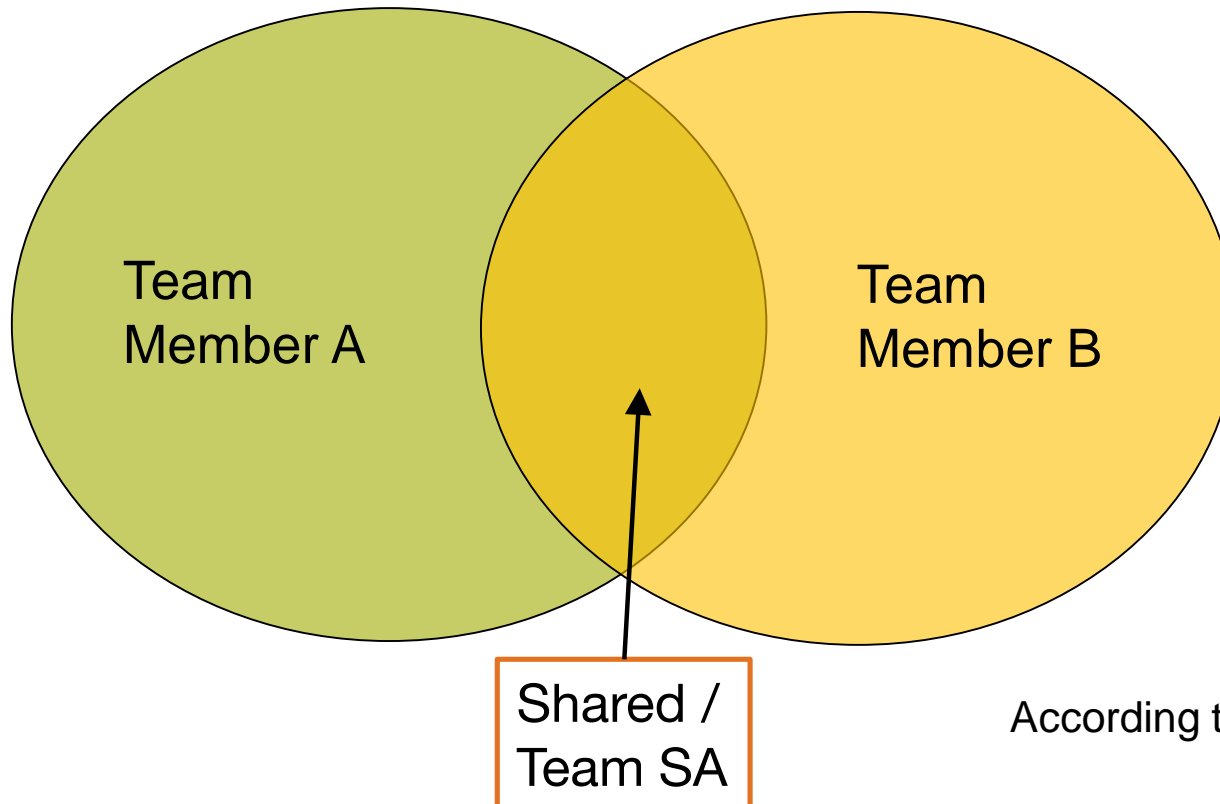
- Shared SA important for teams
- Level of sharedness is influenced by attention and mental models of the crew members (Bolstad, Cuevas, Gonzalez, & Schneider, **XX**)
- Cooke (2004): teams have to solve problems, “detect and interpret cues as an integrated unit”

Measurement of Team SA

- Different approaches; more or less satisfying (Salmon et al., 2006)
- Salmon et al. (2006) come to the conclusion that the „concept of team or shares SA requires much further investigation in itself, which in turn required the provision of reliable and valid measurement procedures“
 - Individuals SA
 - Degree of shared SA
 - Real time capable

⇒ Simulator study with eye-tracking and communication (Dekker, 2002)

Situation Awareness



According to Endsley (1994)

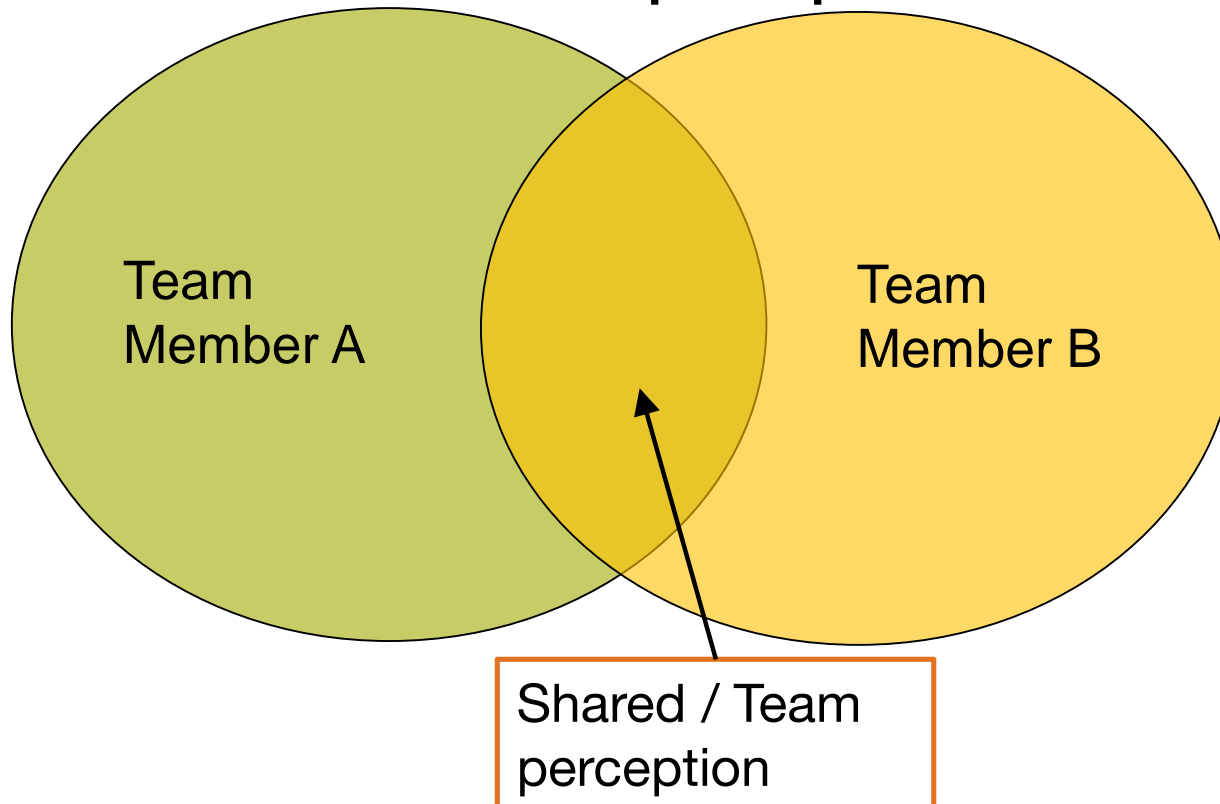
Shared SA = (Team Member A) AND (Team Member B)
Team Bandwidth = (Team Member A) OR (Team Member B)

But – Does that mean we are *good* if we only have a highly shared visual attention?

...probably not... see **Eastern-Air-Lines-Flight 401**

- Approach to Miami
 - gear lowering, but gear indication did not illuminate
 - Whole crew (three persons) worked on the problem (extremely high shared visual attention)
 - Captain leaned against yoke => AP disengaged => A/C lost altitude
 - Airplane crashed
- ⇒ Nobody monitored any other parameter, all were focused on problem
- ⇒ NTSB (1973): the landing gear indication “distracted the crew's attention from the instruments and allowed the descent to go unnoticed.”
- ⇒ The low information bandwidth lead to the accident

Situation Awareness: Level 1 = perception

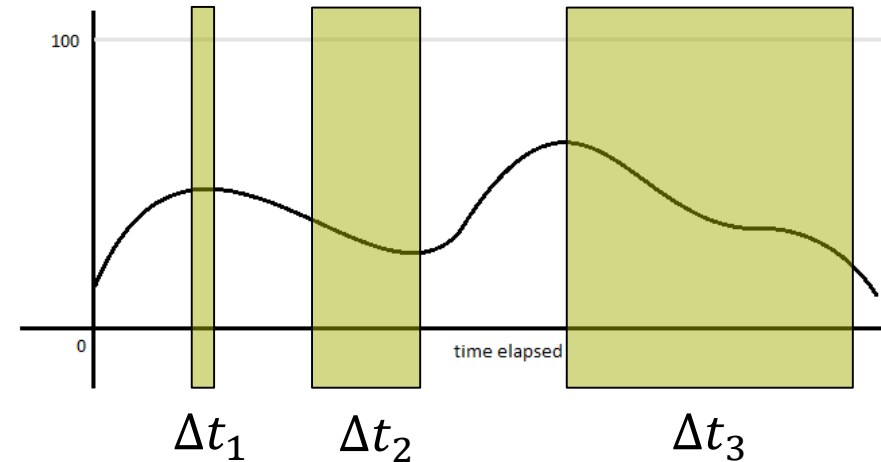


Shared perception = (Team Member A) AND (Team Member B)

Team Bandwidth = (Team Member A) OR (Team Member B)

Shared Visual Attention

- Looking at the **same** indications
- At the **same** time / time slice?



Why Shared Visual Attention (SVA)?

It might be...

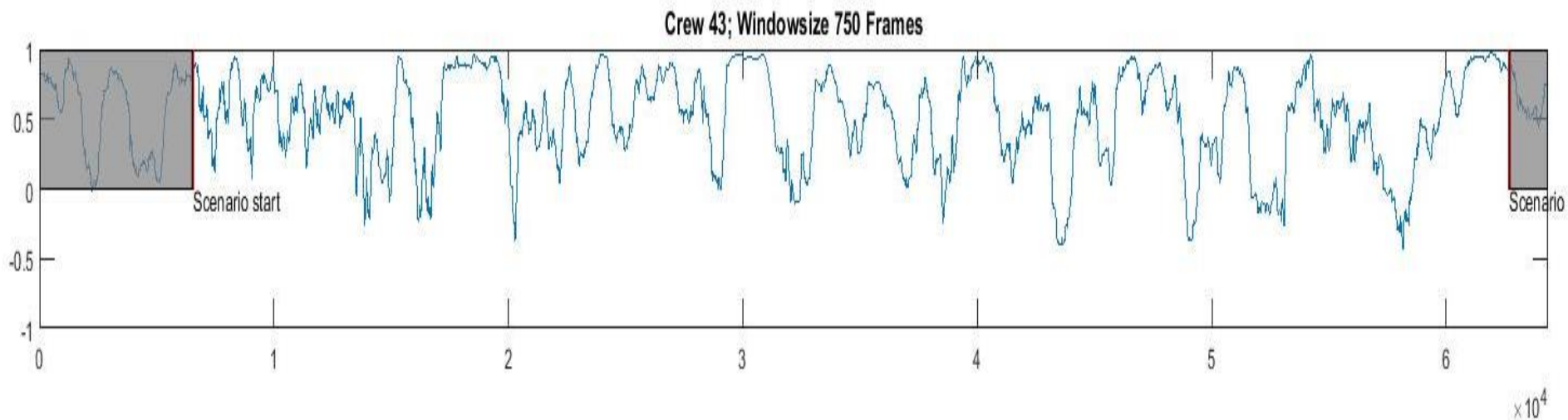
... that a **high shared visual attention** in some phases (e.g. before a decision making situation) is **predicting** good **pilots' performance**...

... that in other situations, low shared attention combined with **effective communication** is better...

Measuring Shared Visual Attention

- Gaze proportion (dwell time) on AOIs?
- Number of fixations on AOIs?
- Within a specific time slice

⇒ Pearson correlation, moving average filtered (e.g. 750 frames = 30 sec.)



Shared Visual Attention

- What do these results tell us?
- Is $r = .7$ *high* in a cockpit environment?
- Or just random, because pilots look at the same things at the same time anyway?

⇒ Permutaton test (actual experimental data set)

⇒ Randomization test (random data)

SVA: Randomization & Monte Carlo Test

- Taking all data
- Differentiating between (all together) CPT and (all together) FO (but rather PF, PM)
- Differentiating between CPT and FO of **one crew**

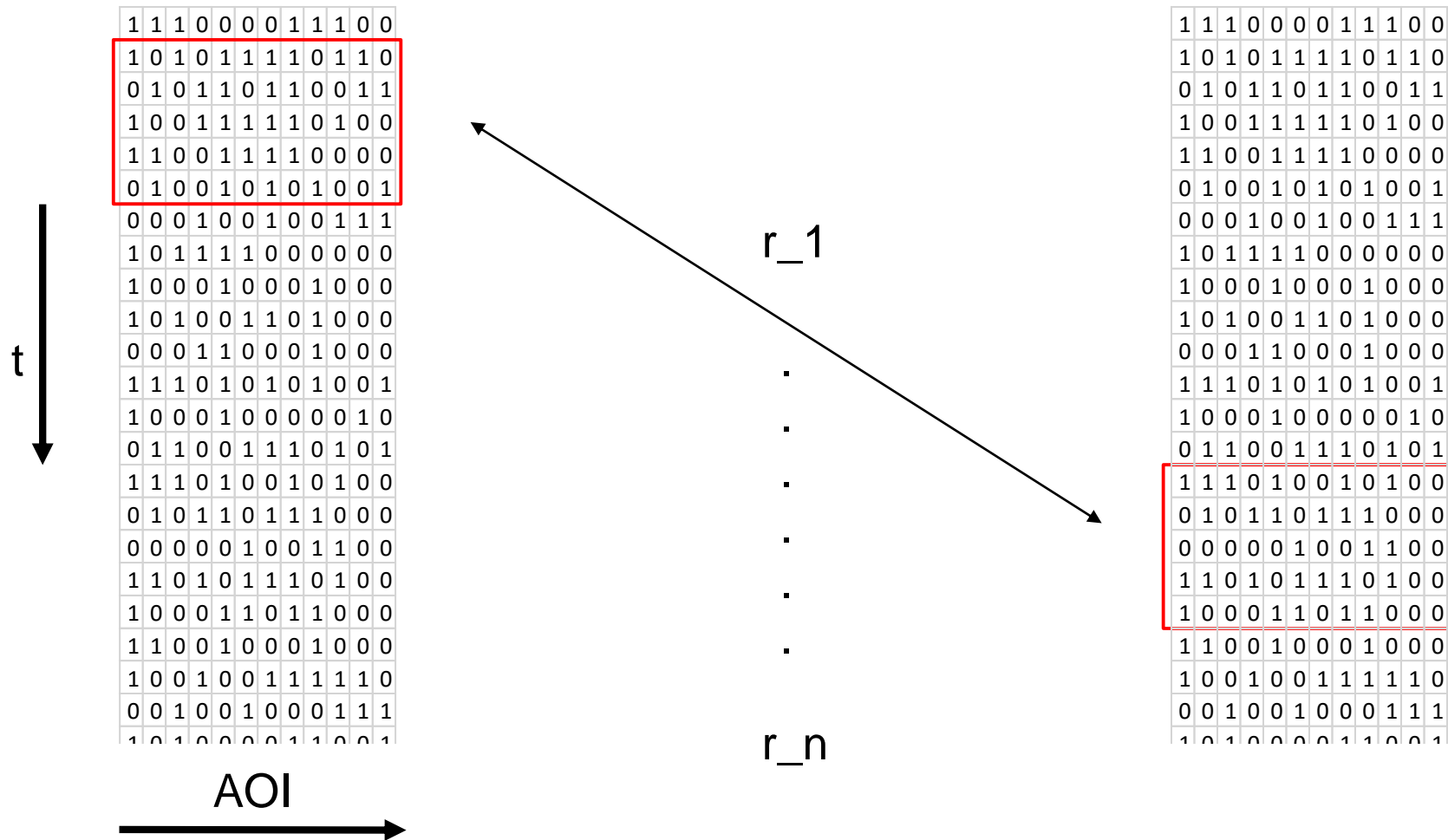
⇒ **Comparing those distributions might be interesting**

⇒ Are there crews, where the two pilots' overall gaze behavior is very similar?

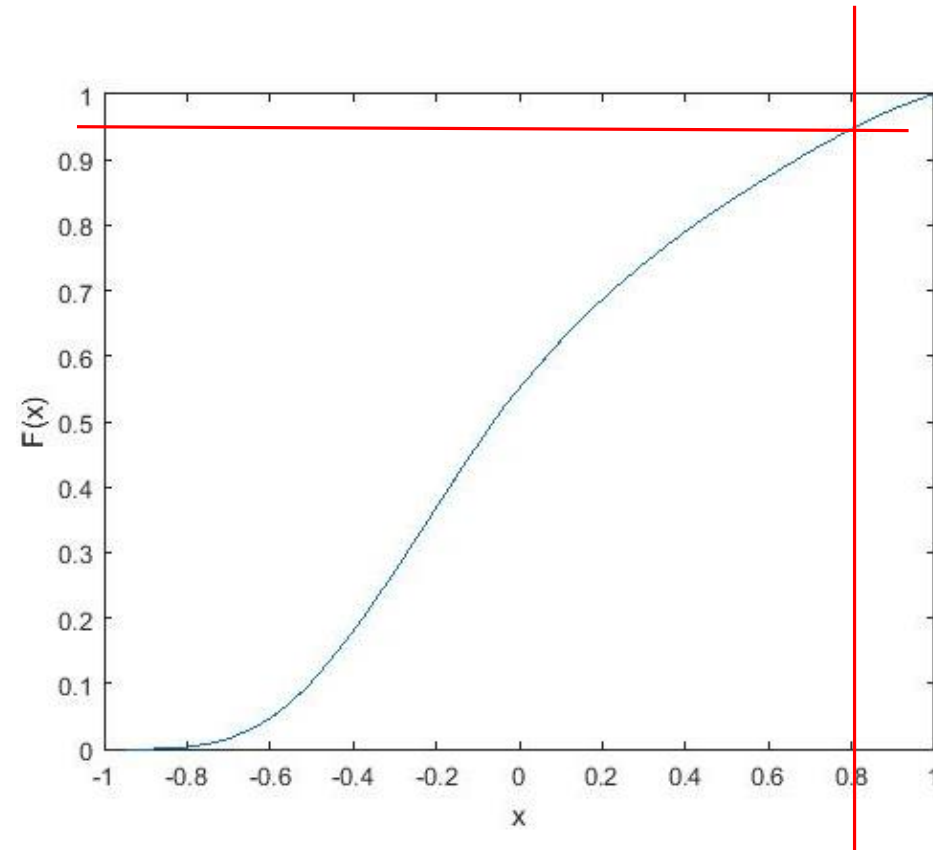
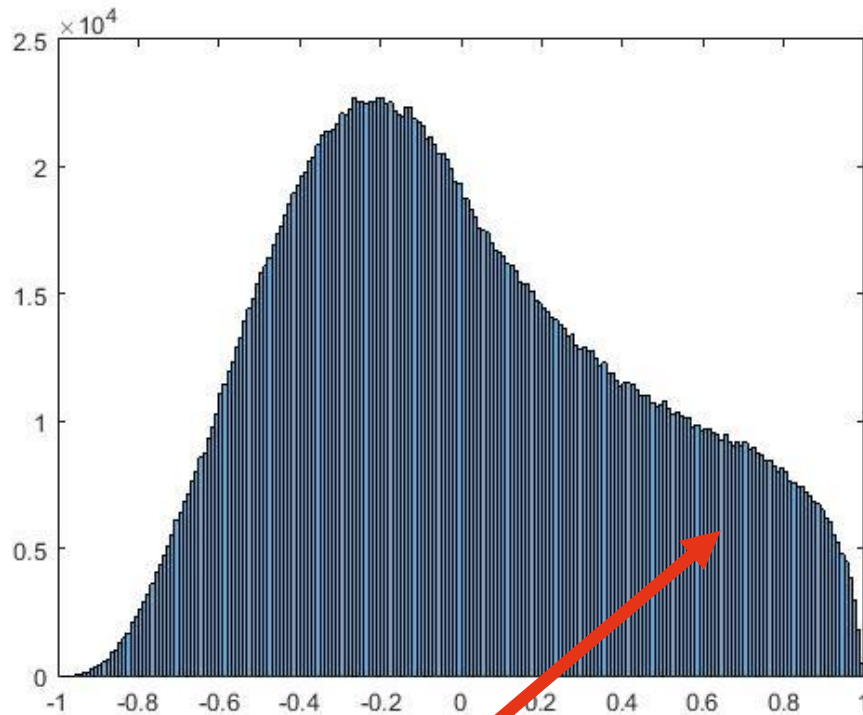
⇒ What leads to success? High correlation in overall behavior or in time-specific behavior?

⇒ Or variance?

SVA: Randomized real data (n=1,000,000 calculations)



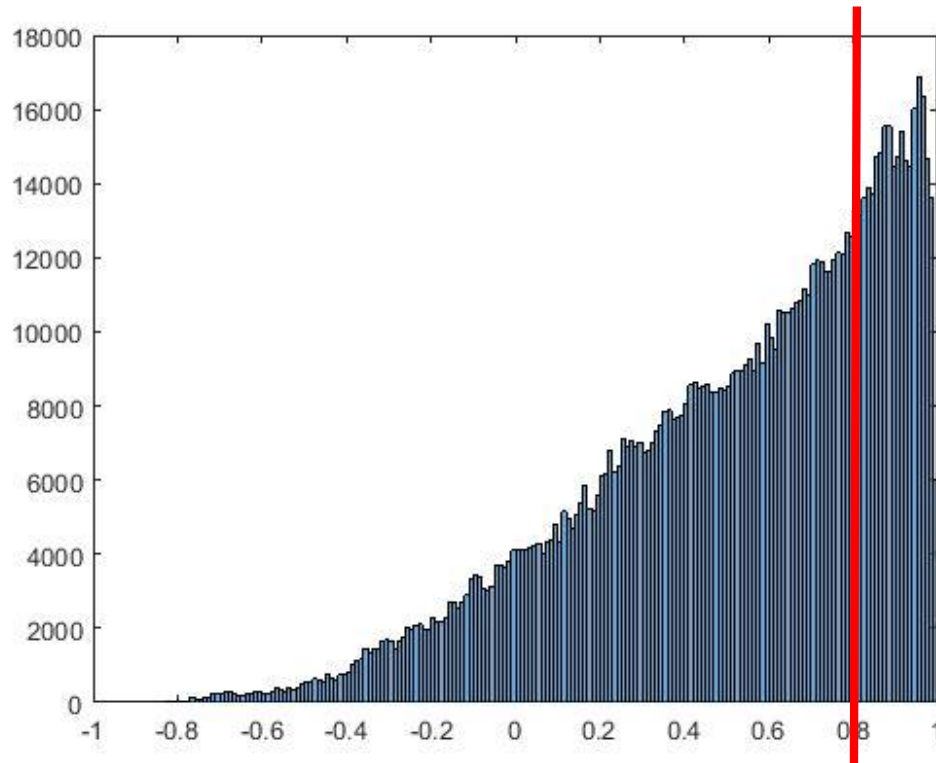
SVA: Randomized real data



- ‚super‘ AOIs
- Internal structure (often fixating on AOI1 and AOI2 at the same time?)

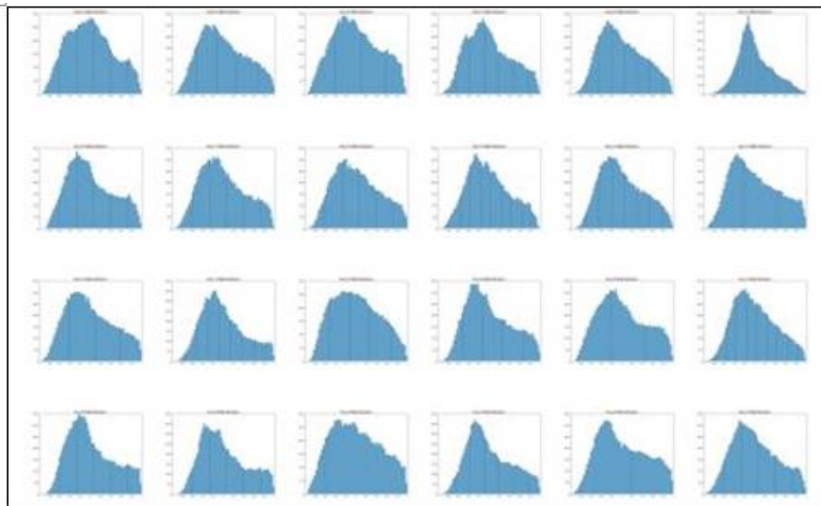
$$r(p = .95) = .81$$

SVA: Synchronized real data

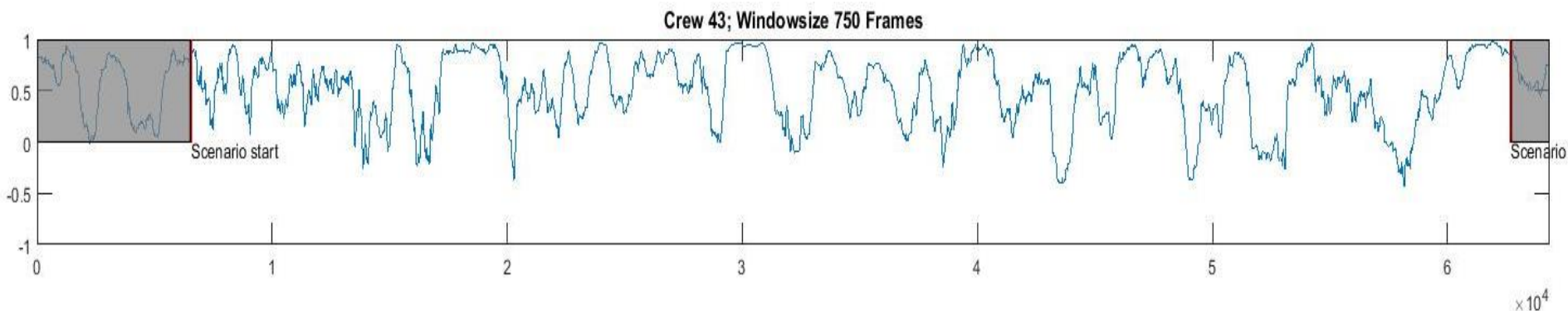
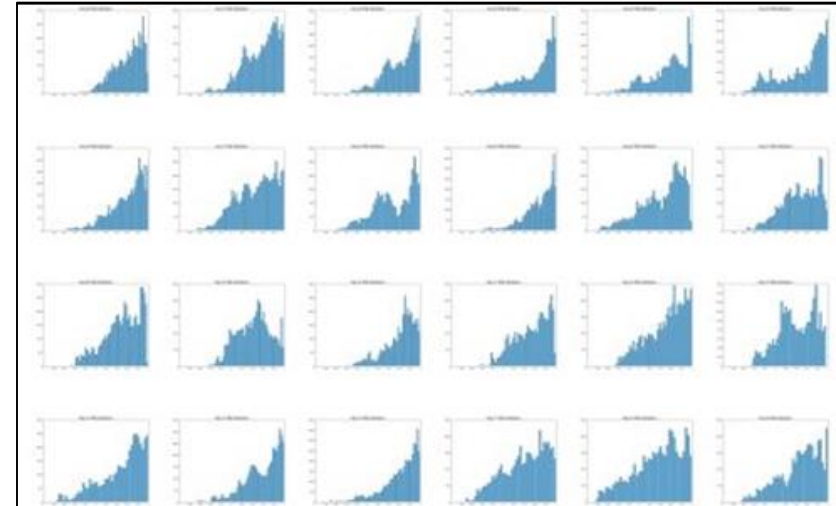


- *Different* distribution
- 28.74% of the pilots' visual attention correlation values are statistically significant on the .95 level

SVA: Individual Distributions & time dependencies



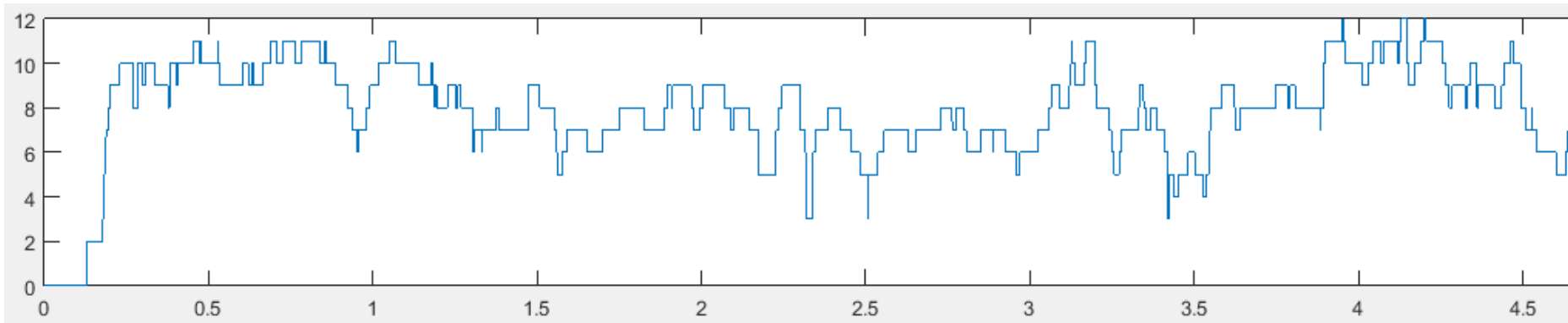
versus



Team Bandwidth (ongoing analyses)

Which / how many AOIs were checked by the crew (as one entity) within a specific time window?

Example of one crew; window time = 30sec.



Next steps:

- Joint attention / RQA ?
- Combining shared visual attention and team bandwidth
- Relating both measurements to performance indicators

Future

- Real time application
- E.g. more salient cues / adaptive displays in case crew members' shared visual attention is too low or in case crew's bandwidth is too low

Thanks to the two unknown reviewer!

And thank you all for your attention (visual and auditory)!

Questions?
Comments?
Ideas?

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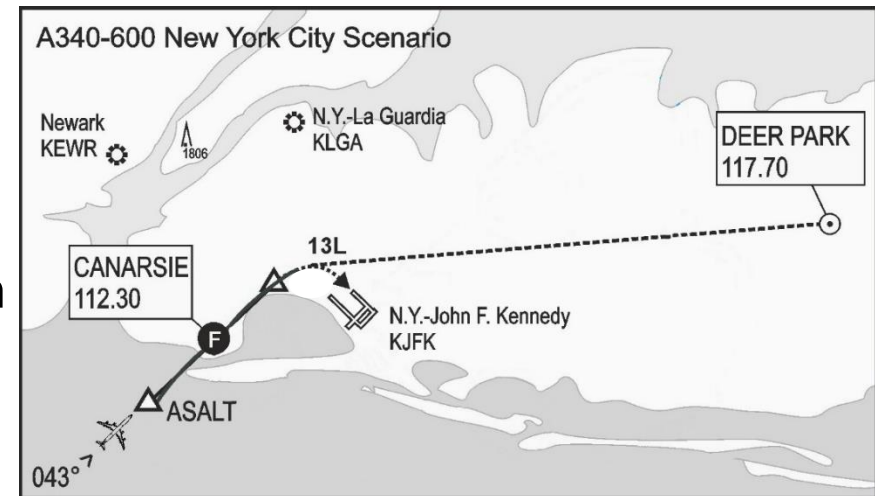
BACKUP

METHOD – Pilots & Scenario

- 120 pilots holding valid ATPL with appropriate type ratings
- Pilots were scheduled for participation as part of their working time
- Participation in this full-flight simulator experiment was not voluntary

Approach scenario:

- Approaching New York (A 346, long haul crews) on a visual approach; fuel on board for 1h
- When lowering the gear, hydraulic system malfunctioned; nose gear not down and locked; fuel on board for 30min due to high aerodynamic drag
- Go-around and procedures



METHOD – Scenario & Initial Rating

- When extending the flaps, they jammed; 360 or aborting approach; fuel on board for about 15min; scenario for rating began here
- FOR-DEC (on which they were trained on) or recognition primed decision, performing procedures and checklists, or aborting them
- Landing

Initial Rating:

- Based on the instructor operating the simulator
- Selecting four videos showing the same scenario with different performance levels (outstanding, medium-high, medium-low, poor) of the crew members

